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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

April 1942 as
Confidential Bulletin

CONSTRUCTION OF FINNED ALUMINUM MUFFS FOR AIRCRAFT-ENGINE CYLINDER BARRELS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL BULLETIN

CONSTRUCTION OF FINNED ALUMINUM MUFFS FOR AIRCRAFT-ENGINE CYLINDER BARRELS

Langley Memorial Aeronautical Laboratory

Summary.- This report describes the material, cutting-tool development, and machining procedure used in constructing an air-cooled cylinder barrel having a cooling muff with 2-inch fins spaced 1/8 inch. Details of two types of thread form used for the barrel to head assembly with the cooling muff are also presented.

Introduction.- In the construction of aluminum-finned aircraft-engine cylinder barrels, the NACA has used an aluminum muff slipped over and shrunk to the barrel before assembly with the cylinder head. This procedure is the current Pratt & Whitney practice on the R-2800 engine. It is of historical interest to note that the original Lawrence air-cooled engine used a form of aluminum cooling muff. The cooling muff of the Lawrence engine was an extension of the aluminum-alloy cylinder head into which was shrunk a steel liner.

Cylinder-barrel muff.- The cylinder-barrel muff is machined from an aluminum-alloy forging. The forging may either be of the pierced or solid type. One muff machined from an aluminum-alloy casting was used, but experience indicates that the forging has a higher thermal conductivity and considerably better physical characteristics. The forged material used was 17S-T, a dural alloy. The hardness of this material is of considerable importance in the successful machining of the fins. It was found that machinability improved with hardness although no attempt was made to determine the limits on either end of the hardness range. In general, it may be stated that when the hardness was less than Rockwell 90-F the forging was too soft to machine. Good machinability was obtained up to the maximum hardness tried, Rockwell 100-B. The hardness of the forging was tested before machining and when it was found to be below Rockwell 90-F the following heat treatment was used: The forging was heated to 930° F and held for approximately 1 hour; then the hot forging was plunged into cold water. The quantity of water was such that its temperature did not rise above 110° F.

As dural is an age-hardening alloy, it cannot be machined for several days after the heat treatment. Immediately after heat treating it was softer than before treating, but the subsequent age hardening increased its initial hardness. The muff was designed to have fins 2 inches deep and 0.050 inch thick with a spacing of 0.125 inch (fig. 1).

Cutting tools.- The most difficult part of the project was the development of cutting tools for machining fins of this depth and spacing. The thickness of the gang cutter's blades limited the desired minimum space between fins; however, the blades could be spaced to give any desired fin thickness. Six blades were used in the cutter although possibly more could be used. Two gang cutters were used; the first set of cutters was used for a roughing operation and the second set was used for the finishing operation. The blades were made from B. & S. ground stock; a sketch of the form found best is shown in figure 2. The only difference in the roughing and finishing tool was a few thousandths inch in the blade width which allowed the chips to come out of the work more freely.

The procedure for machining the fins after the initial rough turning operation was to take the first cut with the roughing tool to a depth of 1/2 inch. The roughing tool was then used alternately with the finishing tool making cuts of equal depth with each tool until the desired depth of the fins was obtained. A single-blade tool was used for the radius at the root of the fins. (See fig. 3 for photograph of finished muff.) After the fins were cut, the muff was finished bored to give the desired shrink fit on the cylinder barrel. The muff was heated to about 450° F for this assembly. The steel barrel (fig. 4) was machined to a true cylindrical form leaving approximately 0.135 inch wall thickness for a cylinder of 5¾ inches bore. The finish is comparable to that of the best turned finish found in commercial practice.

Thread forms.- In the first few cylinders assembled by the NACA the "Aero" thread was used (fig. 5). This type of assembly is identical with that used by the Pratt & Whitney Company, except that they use an 8-pitch thread; whereas the NACA used a 12-pitch thread. The reason for the change in thread pitch was to give a shallower thread in the steel barrel and thereby increase the strength of the barrel at this point.

The "Aero" type of thread as applied to cylinders is a formed wire of bronze or steel wrapped into suitable spiral grooves of the desired pitch machined on the barrel. The upper end of the formed wire is peened into a small hole in the top of the barrel; the trailing end is free to creep during assembly. Using an 8-pitch thread it may be possible to make the assembly with the formed wire held to the barrel by sweating with soft solder. Both peening and sweating were used for the 12-pitch thread.

Later NACA cylinder assemblies have been made using a thread construction of NACA design. This design uses a spiral groove on the barrel similar to that used in the "Aero" thread design. However, no formed-wire insert is used. That part of the thread corresponding to the rounded part of the formed wire of the "Aero" type thread is cut directly in the aluminum head with a formed tool. The details of this thread construction are shown in figure 6. Several cylinders using this construction have been power tested up to 1500 pounds per square inch cylinder pressure with no signs of failure.

The object of the NACA thread design was to obtain a simple thread easy to assemble.

Shrink fits.- With either thread form the cylinder head is heated to approximately 550° F and upon removal from the oven is quickly screwed onto the barrel clamping the muff between the head and the shoulder which was provided on the barrel. The head has a shrink fit on the barrel of 0.019 inch. This shrink chokes the bore of the barrel at the top of the cylinder by about 0.016 inch. After assembly the hold-down stud holes are drilled in the cylinder flange in their proper relation to the head.

In the NACA assemblies, the muff is designed to have an 0.008-inch shrink fit on the barrel. The effect of this shrink on the barrel bore seems to depend on a number of factors which have not yet been segregated. In some assemblies, as little as 0.002- to 0.003-inch reduction is obtained in the nominal bore size because of the shrinking on of the muff. In other assemblies, as high as 0.006- to 0.008-inch reduction has been obtained. If the reduction in bore size is from 0.002 to 0.003 inch, only light honing is required to place the cylinder in service. If the reduction in bore is larger than 0.002 to 0.003 inch, it should be honed to the nominal size. Some undersize is permitted with the cylinder cold so that under operating conditions a true bore will be obtained.

General remarks.- Buckling of the fins on the muff immediately after machining may be corrected by inserting steel spacers of the correct thickness between the fins and heating the assembly to 800° F and allowing to cool slowly. Staggered notching of extremely wide fins is suggested as a means of preventing buckling in service. For equivalent weight of fin material, the cooling using the aluminum muff is approximately twice that for steel fins turned directly on the barrel. This basis of comparison only holds when optimum fin dimensions are used on both aluminum muff and steel barrel.

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NACA

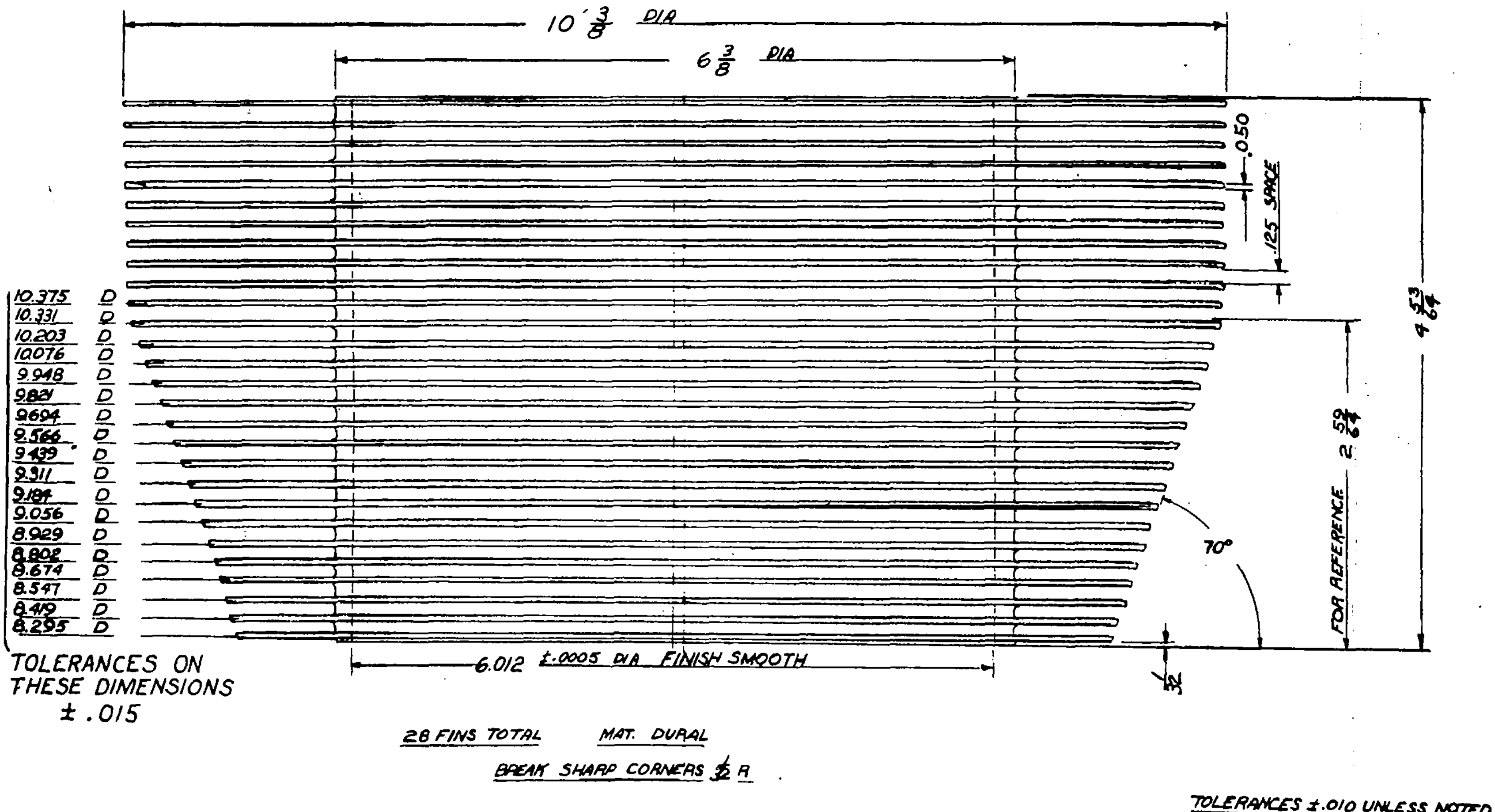


FIGURE 1.-

Fig. 1

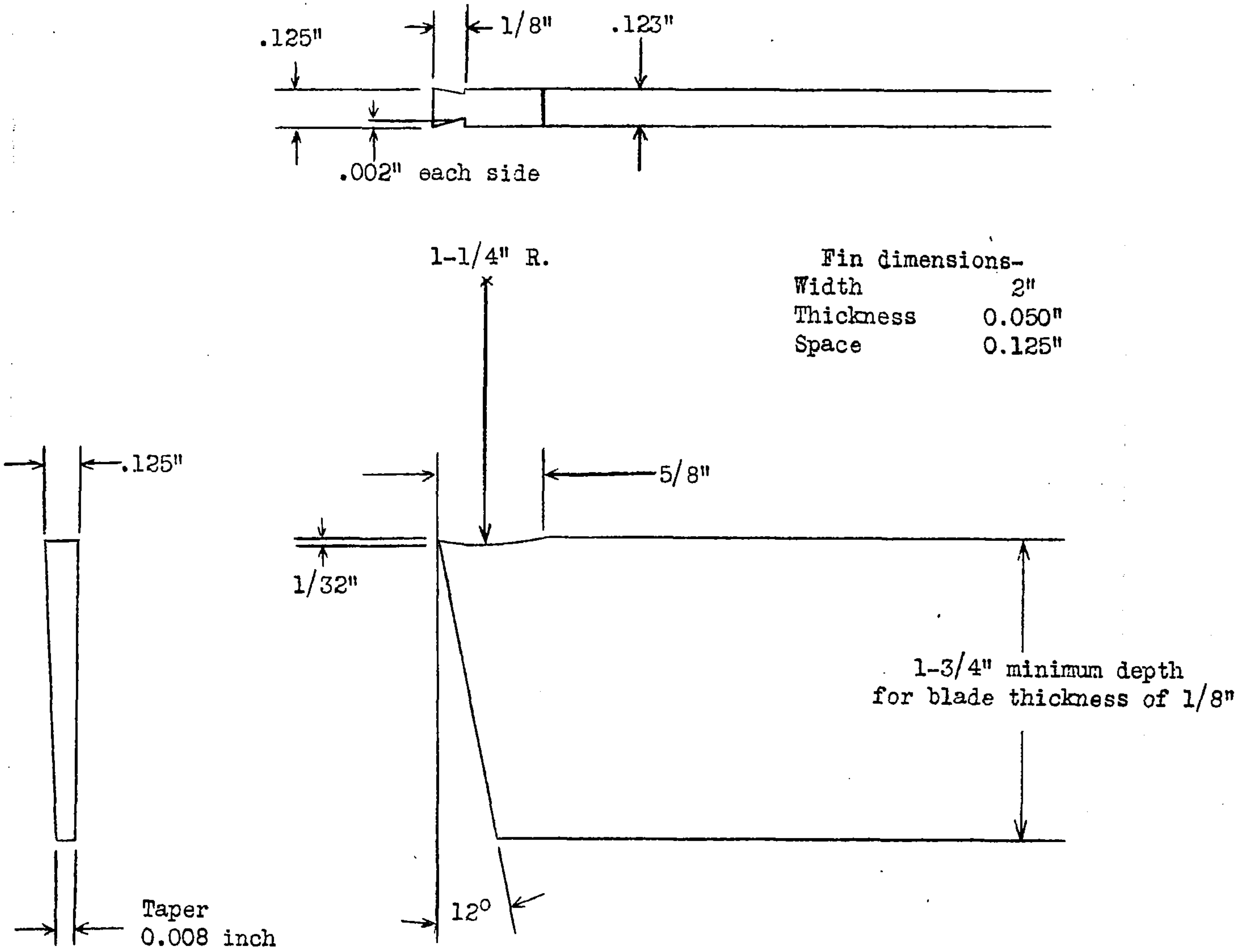


Figure 2.- Gang-cutter blade.

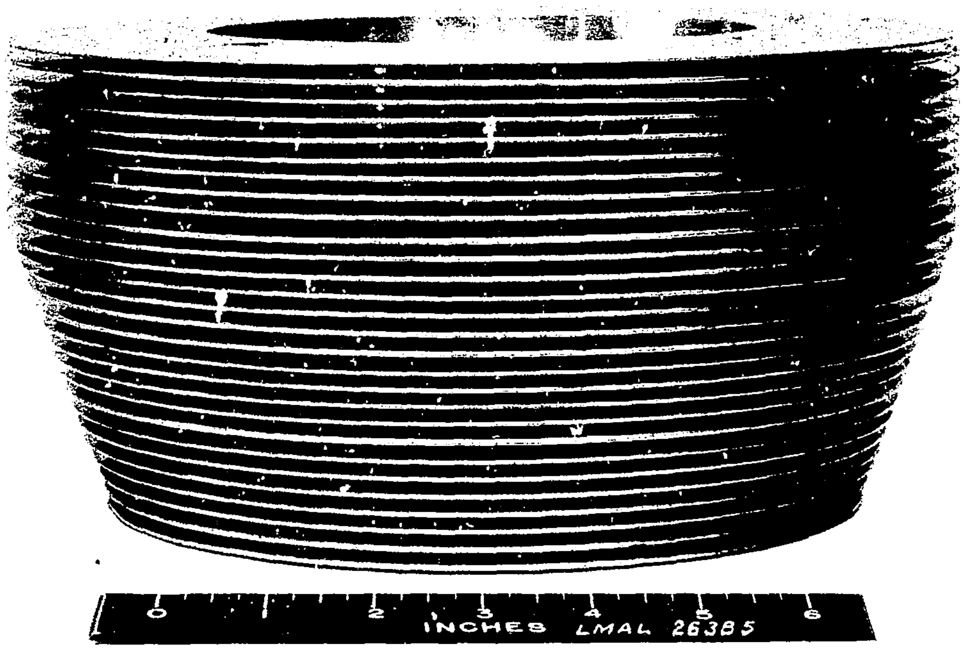
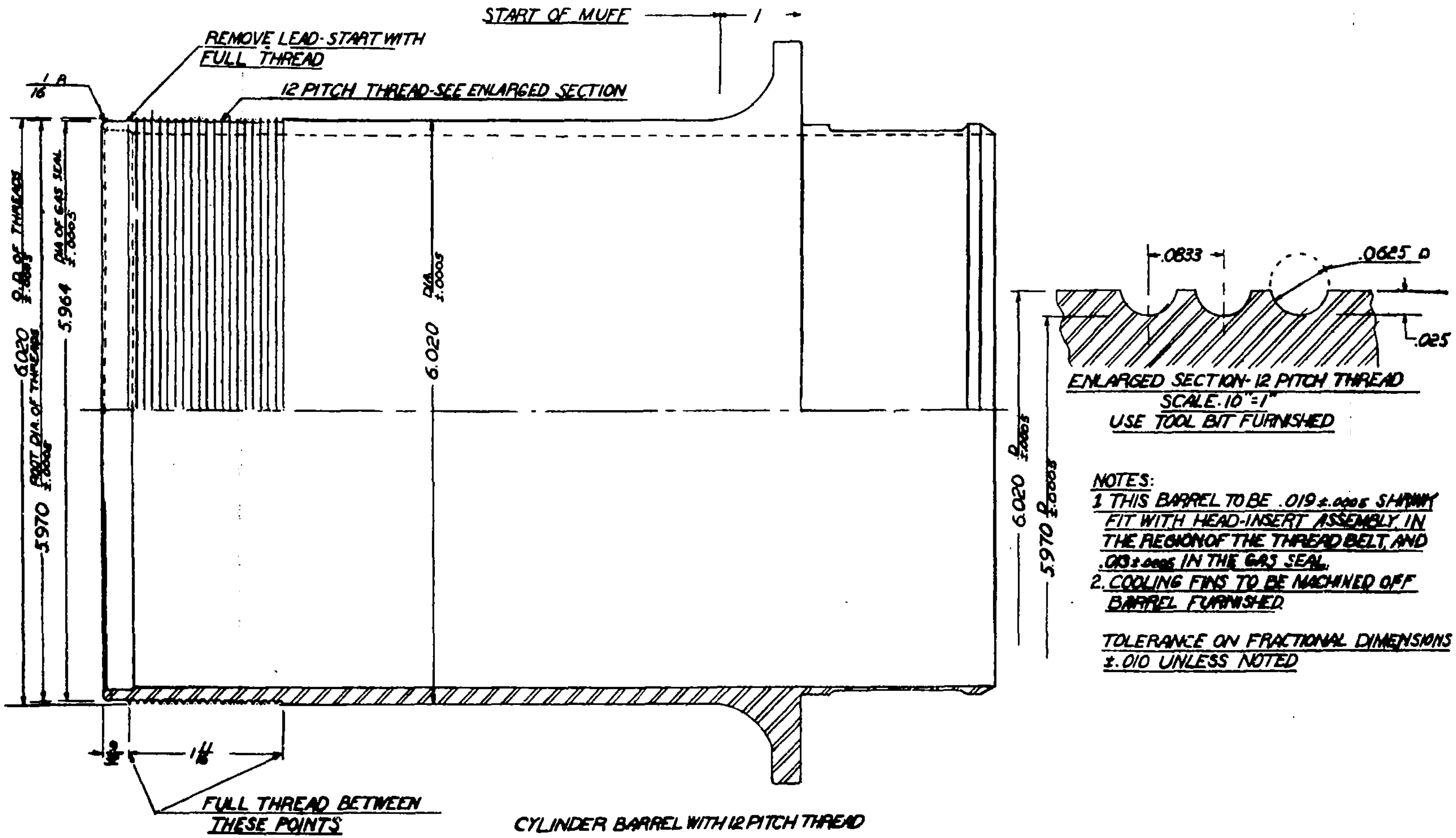
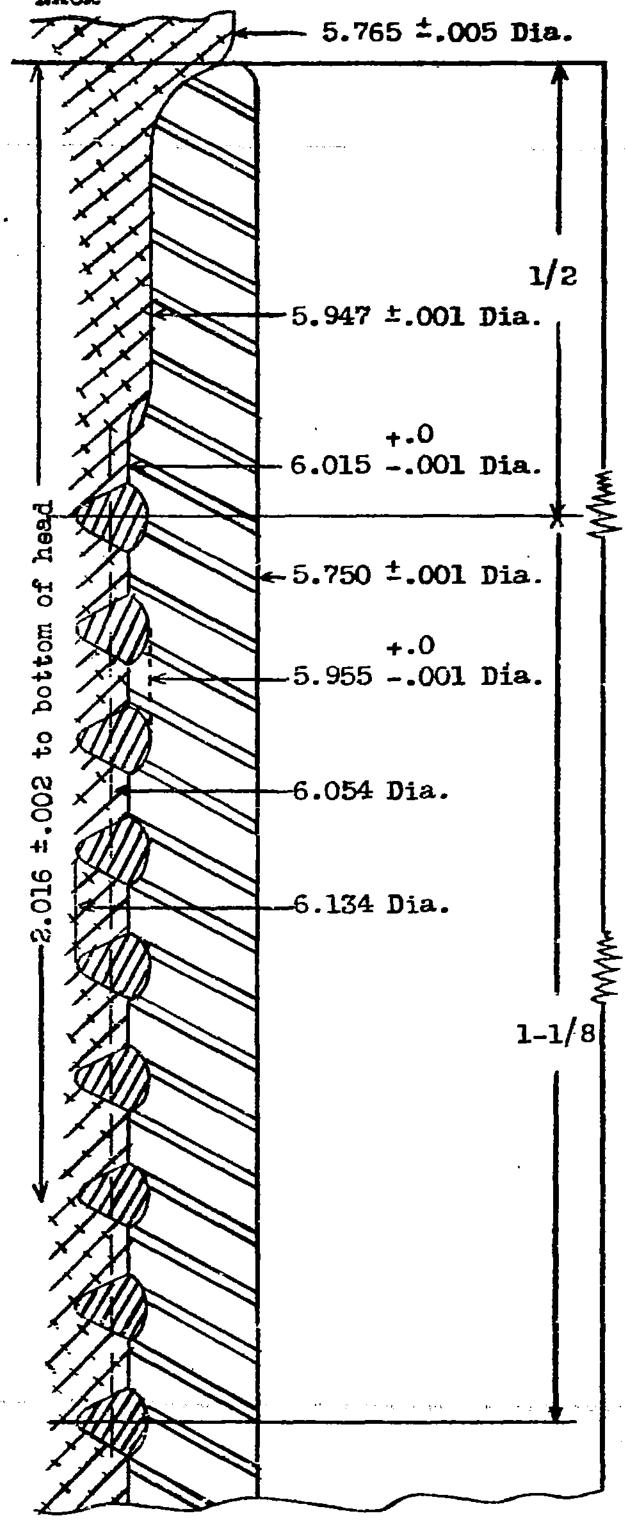


Figure 3.- Aluminum muff, 2-inch fins, 1/8-inch space between fins.

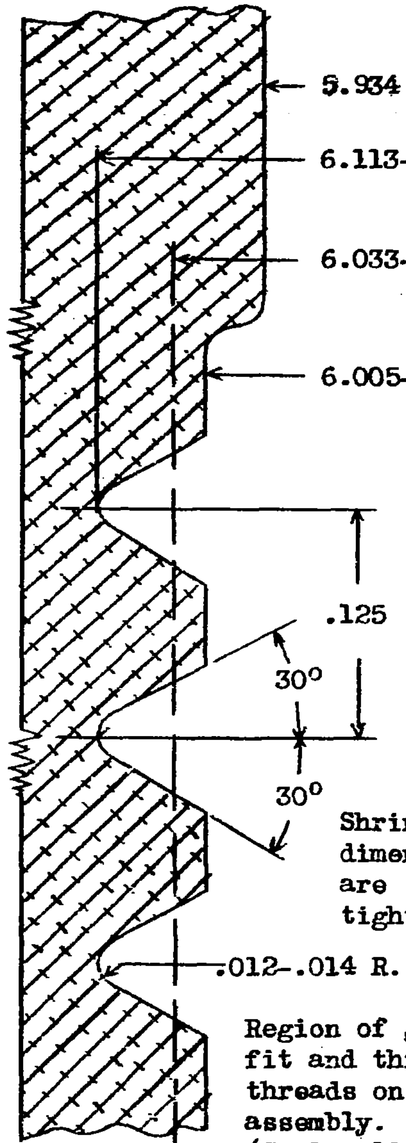


CYLINDER BARREL WITH 12 PITCH THREAD

FIGURE 4.- A.C.C.I. ENG.



Cylinder barrel assembled in head, 9M wire insert, 8 pitch, 8 complete threads. (Scale- 5 times size)



Region of gas tight fit and three topmost threads on head before assembly. (Scale- 10 times size)

Wire and barrel to be tinned for soldering top end of insert to barrel with copper soldering iron. Do not use torch.

Notes-
Unless otherwise specified break all sharp edges. Allowable variations on finished dimensions, fractions ±.010, decimals ±.005, angles ±2-1/2°

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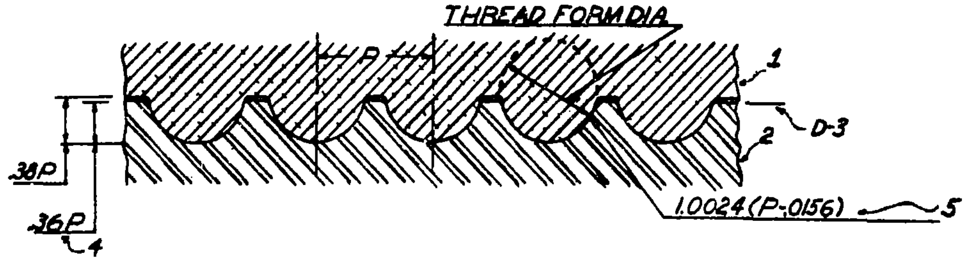
Figure 5.- Cylinder barrel to head connection-8 pitch A-T



SECTION SHOWING NACA THREAD FORM

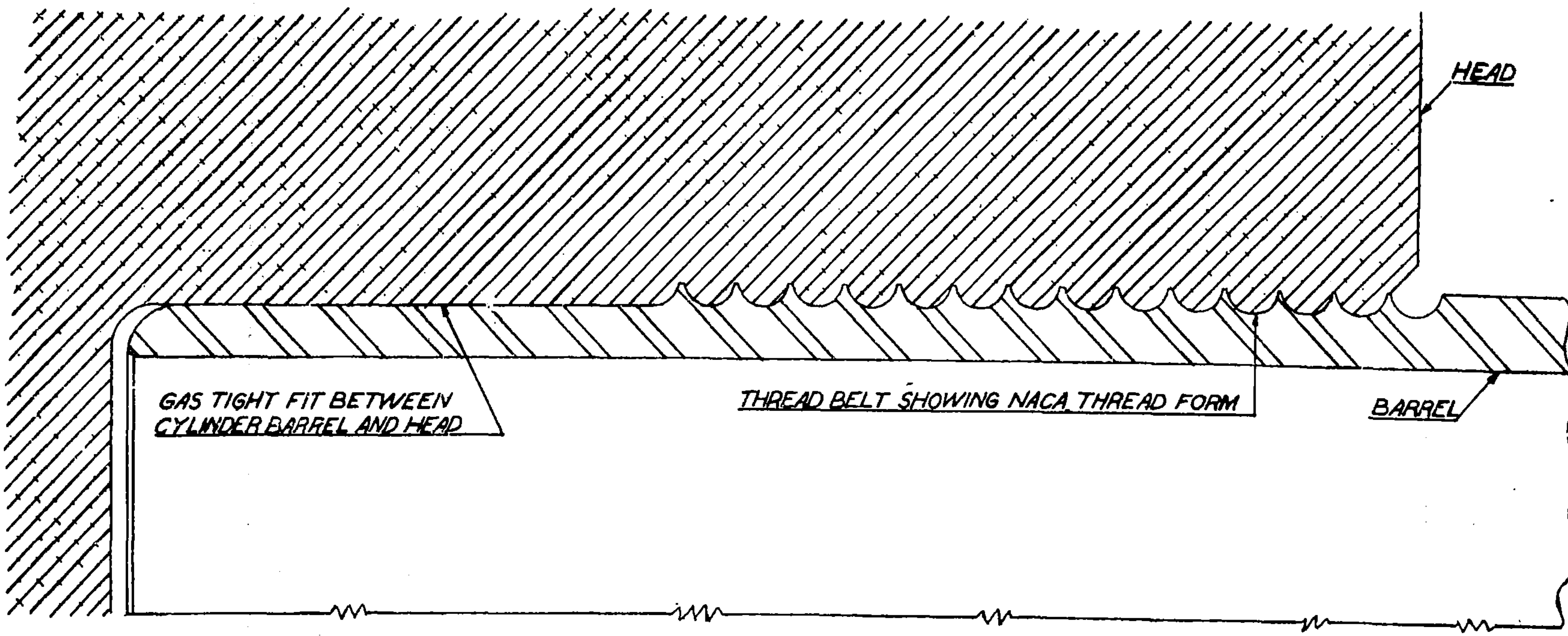


FIGURE 6.- SECTION SHOWING CYLINDER ASSEMBLY